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THE EFFECT OF WINDS ON THE UNDERWATER LOW FREQUENCY AMBIENT NOISE--ETC(U)

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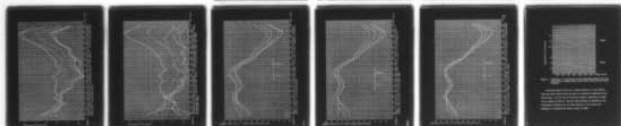
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THE EFFECT OF WINDS ON THE UNDERWATER LOW FREQUENCY AMBIENT NOISE RECORDED
AT A LOCATION OFF THE WEST COAST OF THE UNITED STATES.

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THE EFFECT OF WINDS ON THE UNDERWATER LOW FREQUENCY AMBIENT NOISE RECORDED AT A LOCATION OFF THE WEST COAST OF THE UNITED STATES. An examination of the dependence of noise in the frequency range of 8.9Hz to 446Hz on winds at a maximum range of 1400 nm from the receiving facility.

by

W. L. Frisch and T. S. Scanlan

This memorandum discusses a study conducted under NEL Problem I20451 (SF 101 03 15, Task 8119) by the authors which was designed to: (1) evaluate the usefulness of employing the weather map plotting chart presentation of meteorological data in connection with (2) the determination of the dependence of low frequency ambient sea noise on winds measured very near the sea-air interface at various ranges from the recording facility. This memorandum has been prepared because it is believed that the information may be useful in this form to others at NEL and to a few persons or activities outside NEL, and should not be construed as a report as its only function is to present information on a limited portion of the work which was done on the above-mentioned problem.

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INTRODUCTION

↘ It is well established that the interaction of wind and sea at their interface may result in the production of significant levels of noise, particularly in the frequency range of about one hundred to several thousand cycles per second, when the noise is measured directly under or very nearly under the windswept area.^P It is not so well known what relationships, if any, exist between ambient noise levels in the very low frequencies and storms or wind activity measured at great distances from the hydrophone. It has been the purpose of this study to: (1) determine if and to what degree such relationships might exist and how this contributes to the character and magnitude of the sea noise now under observation, and (2) evaluate the usefulness of employing the weather map plotting chart presentation of meteorological data in the above. ←

METHODS

It was first necessary to obtain wind and storm data in quantity for the North Pacific Ocean in order to compare it with ambient noise data available for this area. Weather maps were initially chosen for this purpose since they were the most readily available form of such information. The most informative marine weather maps available were those produced by Fleet Weather Central for the North Pacific Ocean. These were made available by U. S. Fleet Weather Facilities at North Island, San Diego.

It was then necessary to develop a means of reducing this data into a more compact and usable form. It was first decided to construct windfields (isotachs) by utilizing a geostrophic* scale in conjunction with the already plotted isobars on the map. It was found that this method yielded wind speeds which were not always in good agreement with those reported by ship

*Derived from Coriolis and pressure gradient forces (neglecting frictional and other forces).

weather reports at those same locations. Evidently geostrophic scales, which neglect frictional forces, do not yield reliable results for wind speed over the ocean at low altitudes. Since this study was concerned with wind speed near the ocean's surface, the use of geostrophic scales was discontinued, and only those wind speeds reported directly by ship-board personnel were thereafter considered. This meant that wind data was not uniformly available over the ocean from day to day, and in fact that some areas consistently yielded more data than others (e.g., along shipping lanes).

Other problems existed. The weather data was recorded only every six hours daily (0000, 0600, 1200, and 1800 GMT). Wind speed was recorded only to the closest 5 knots, and accuracy of measurement of wind speed between various ships is further compounded by the locating of anemometers on different positions of the ships' superstructures. During times of very high winds, there tended to be fewer data. With these limitations in mind, it was decided to use an averaging technique which would smooth the data without biasing it too strongly.

This averaging of wind speeds was accomplished by observing wind speeds which were approximately equidistant from some reference point close to the recording facility. This was done by dividing the adjacent ocean into shells and sectors with incremental radii of 200nm. An example of this type of configuration is shown in Figure 1.

The noise data contained background ship noise, and deletions were made for those times that it was obviously present.

The data were summarized as follows: for each shell and sector defined in Figure 1, a mean wind speed was computed. These respective

magnitudes for wind speed in the shells and sectors were compared to ambient noise levels in the third-octave-band series starting at 10Hz center frequency to 400Hz center frequency.

The statistical comparison was comprised of four main parts:

1. A correlation test for comparison of both the mean wind in the aforementioned shells and sectors with broad-band and third-octave-band ambient noise levels.
2. Grouping of wind data into groups which correspond to the modern Beaufort scale, and evaluating corresponding mean ambient noise levels in the third-octave series.
3. A general investigation of the mean, standard deviation, skewness and kurtosis under the assumption that any wind induced ambient noise shift might also change the basic form of the distribution.
4. A correlation test for comparison of log of mean wind and mean wind squared with broad-band and third-octave-band ambient noise levels.

RESULTS

The coefficient of correlation between wind and ambient noise levels for 12 to 20Hz (all frequencies which appear in the subsequent discussion refer to the center frequencies of the third-octave-band series) appears to be much less dependent on the maximum radius over which cumulative wind averages are determined compared to the correlations at other frequencies (see Figure 2). With the exception of this frequency range, all coefficients appear to decrease with increase in maximum radii over which cumulative averages were determined. At frequencies greater than or equal to 25Hz, and for increases in maximum radii of computation, all coefficients

(for radii greater than 1000m) appear to approach different asymptotic values; in this situation, only those values for 250Hz and 320Hz show any statistical significance. The smallest number of data points for any of the computations was 272. At a 1 per cent level of statistical significance, this corresponds to a minimum correlation coefficient of about .16.

There was an expected higher correspondence between the wind speeds in those shells closest to shore and the noise, since the noise was measured at some point relatively close to shore. This was particularly evident for the higher wind speeds to the extent that experience has shown that a significant correlation exists between prolonged times of high wind and prolonged times of high ambient noise. It is much more difficult to note a good correlation between data whose period of variation is only on the order of one day or less.

Highest correlation (.55) is at 320Hz, for the closest region in which wind speed was averaged (to a maximum radial distance of 200m). Nearly all of the other frequencies investigated also yielded highest coefficients for the closest range. Exceptions may have been wrought as a result of small data sampling of wind speed in this region.

One very conspicuous feature in the correlation analysis, evident in both the cumulative and wind shell correlations, is the decrease of the coefficient at 400Hz. This is inconsistent with both the usually observed characteristics of high frequency noise-wind dependence and the trend actually indicated by the analysis showing a general increase in magnitude

of the coefficient with frequency for frequencies above 100Hz. The validity of the indicated coefficient for 400Hz is further questioned because of suspected inaccuracy in noise data for this band.

The peculiar grouping of the correlation coefficient for the sector portion of the analysis in the 12 to 20Hz range (particularly 20Hz) was further examined in the individual shell analysis, and the results are not too enlightening. Although the grouping does seem to exist (see Figure 3), at least compared to the other frequencies, the coefficient is too low in all shells at ranges greater than 400nm to warrant a positive statement with respect to statistical significance. Although the cumulative averages at large ranges suggest statistical significance with ambient noise levels, the noise is evidently not correlated with wind in shells considered singly at the same large ranges. Only the comparatively high correlations in the very low frequencies and the 250 to 320Hz region show significant correlation to as far as the second shell (outer periphery at 400nm and inner limit at 200nm).

In the wind magnitude grouping analysis, data points were sorted on the basis of mean values falling within the modern Beaufort number definition² for a particular shell or sector. There was insufficient data to draw any conclusions for the mean values of ambient noise corresponding to the Beaufort No. 1 group or Beaufort Nos. 7 or greater. The results are shown for the first shell (highest correlation coefficient, Figure 4), the second sector (maximum radius of 400nm, Figure 5), and the second shell (minimum radius 200nm; maximum radius 400nm, Figure 6). In each grouping,

the number of points which went into the computations for each of the mean values of sound pressure level for the third-octave center frequencies was nearly the same; however, the smallest number (N) for a particular Beaufort grouping is indicated in Figures 4 through 6.

In general, all three depicted areas show patterns for the respective means of the sound pressure spectrum levels (derived from measured third-octave-band levels) consistent with those frequencies for which the correlation coefficients were highest.

With respect to the other statistical computations made on the Beaufort sorted data, no obvious trends appear in standard deviation, skewness, or kurtosis; evidently, in spite of the interaction, the distributions maintain their nearly normal form, while their mean levels increase.

The correlation test on log wind speed and wind speed squared with ambient noise spectrum levels does not demonstrate any appreciable changes contrasted to the test on simply wind speed to the first power.

The analysis of ambient noise levels in the ocean, whether they be in terms of diurnal periodicities, biologics, ship, or wind-generated noise, nearly always is motivated by the desire for a prediction capability. The best estimate will ultimately be determined by considering all of the causative mechanisms for which we have knowledge together. Even so, the individual component generating mechanisms may be useful in providing a first estimate in certain frequency ranges during times in which they undergo extreme activity.

In the 320Hz band, the regression line prediction model³ yields

$$N_{320\text{Hz}} = .4\bar{V}_w + 33, \text{ for the 200 nm area, with a standard error of}$$

estimate of about 3 dB, where N is noise sound-pressure spectrum level in dB re 0.0002 dyne/cm², V_w is mean wind speed for the area in knots.

CONCLUSIONS

The specific application of weather map plotting charts to the problem of wind - noise - range interdependence is faulty in at least two aspects. First, as mentioned previously, the quantity and quality of meteorological data presentation are inadequate to establish an accurate picture of activity over such large areas. Second is the lack of independence between adjacent areas; high or low values in a particular shell or sector frequently are accompanied by similar values in adjacent areas at the same time. A modification of the approach, which would result in a more valid model, would be to examine similar areas, but under the restriction that neighboring areas have some nearly constant value. For example, one might compare ambient noise levels to mean wind speeds in shell no. 3, during those times that mean wind speeds in shells 1, 2 and 4 have some constant Beaufort value. Unfortunately, the number of initial data points required to supply a sufficient number of points in the sample would be unwieldy.

In general, the trends indicated show dependence in both the high and low ends of the frequency range considered, with an apparent lesser degree of range dependence in the lower frequencies.

The low correlations between wind and ambient noise levels that appear at mid-range frequencies take on their lowest values at 50Hz and 63Hz, and may be related to the influence of traffic noise. With the exception of 400Hz, nearly all of the plots of coefficient of correlation of winds vs ambient noise have an appearance similar to the inverse of spectrum level plots of generally accepted traffic noise characteristics.

RECOMMENDATIONS

To obtain data most useful for prediction of ambient sea noise the following approaches are recommended:

1. Weight individual wind measurements by considering the distance between the position at which the measurement was made and the recording facility.
2. Incorporate study of other meteorological phenomena similarly weighted.
3. Utilize data form made available from ships at sea presented in the form FM 21.A, approved by the World Meteorological Organization (WMO).

REFERENCES

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2. Von Arx, An Introduction to Physical Oceanography, p. 68, Addison-Wesley Publishing Company, Inc., 1962.
3. U. S. Naval Ordnance Test Station, China Lake, California, NAVORD Report 3369, NOTS 948, Statistics Manual, by Edwin L. Crow, et al, 1955.

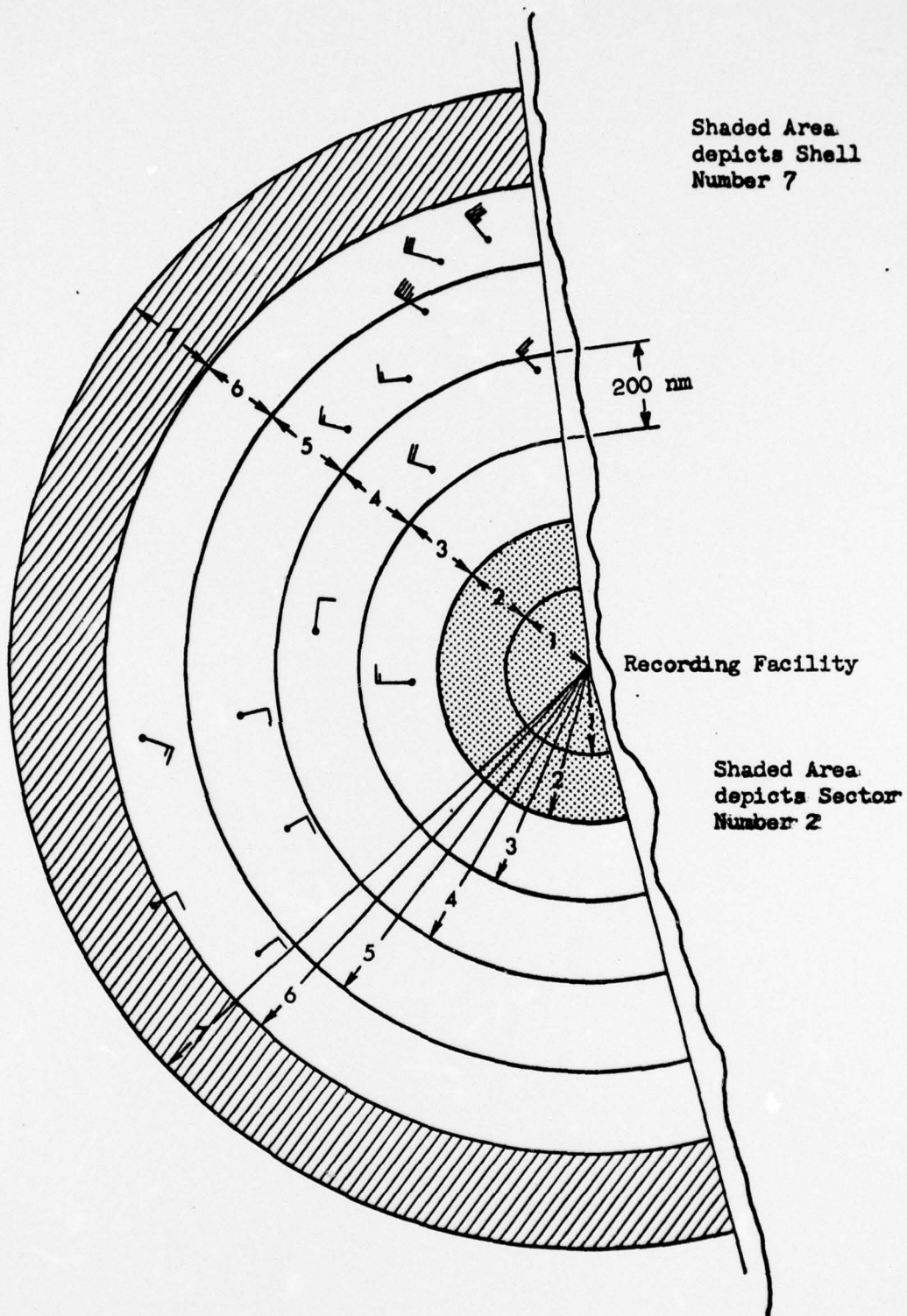


Figure 1. A typical section of ocean-coastline showing construction of Sectors and Shells 1 through 7. Wind speed designators are shown as they might appear on a representative hours' weather plotting chart.

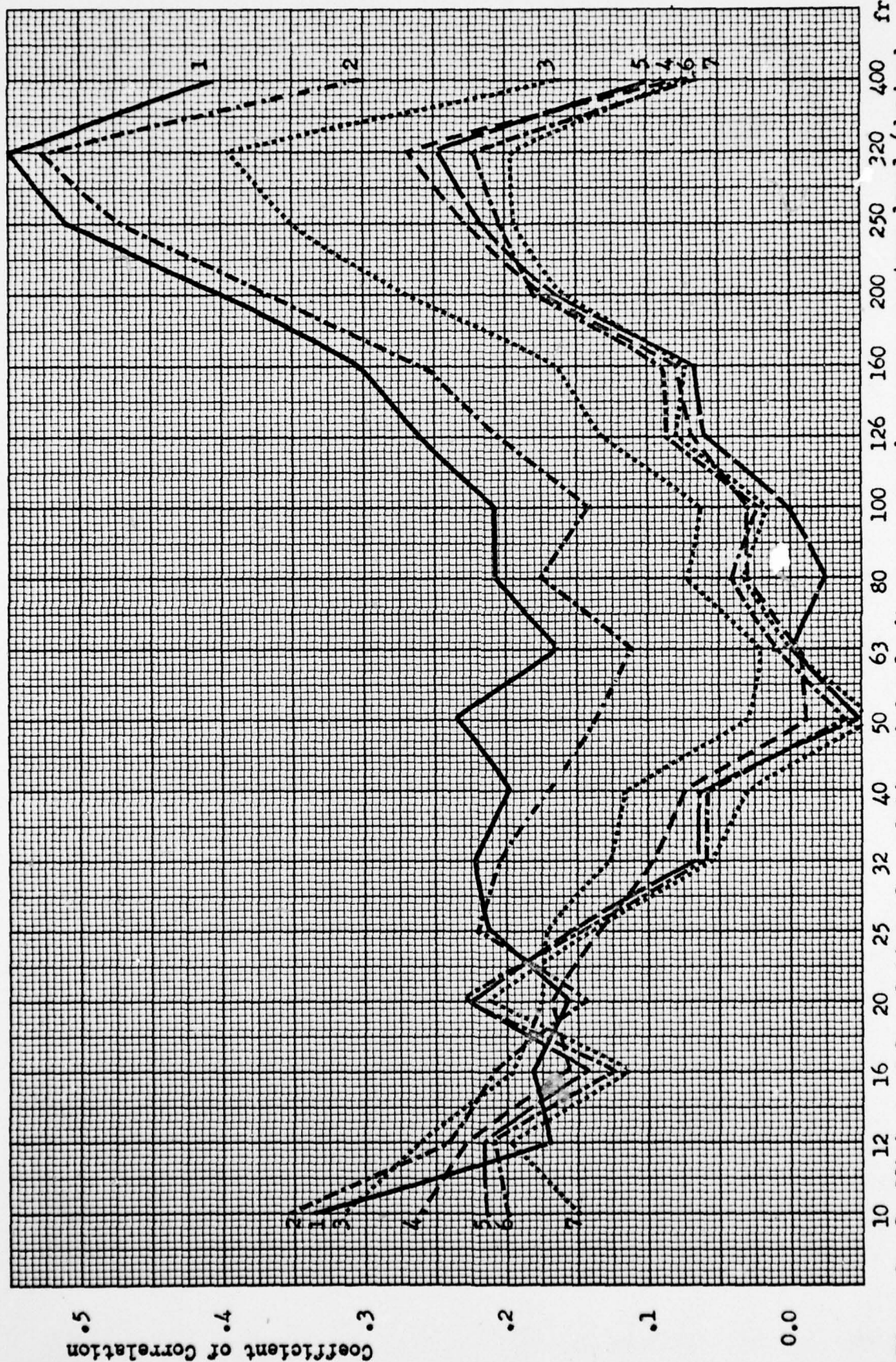


Figure 2. Coefficient of Correlation of cumulative wind velocity versus sound pressure spectrum level (derived from 3rd octave band measurements). Cumulative wind velocities centered in sectors with incremental radii of 200nm. #1 corresponds to 200nm maximum radius, #2 ~ 400nm, ... For the hours 0000, 0600, 1200, 1800Z. Jan thru April 1963.

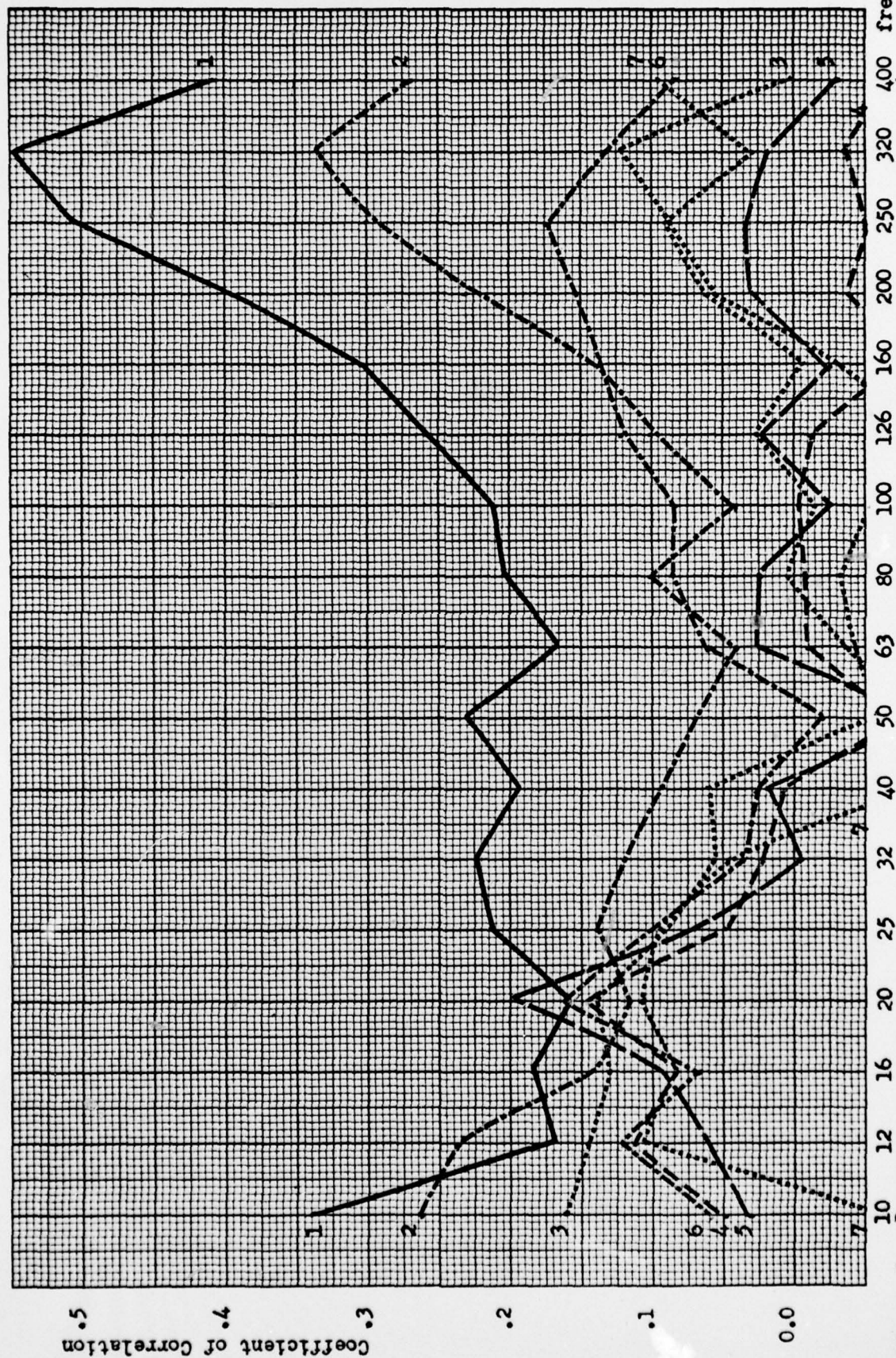


Figure 3. Coefficient of Correlation of wind averages in each shell versus sound pressure spectrum level (derived from 3rd octave band measurements). Wind shells have constant radial difference of 200nm, #1 corresponds to 0 to 200nm, #2 ~ 200 - 400nm, ..., for the hours 0000, 0600, 1200, 1800Z, Jan thru April 1963.

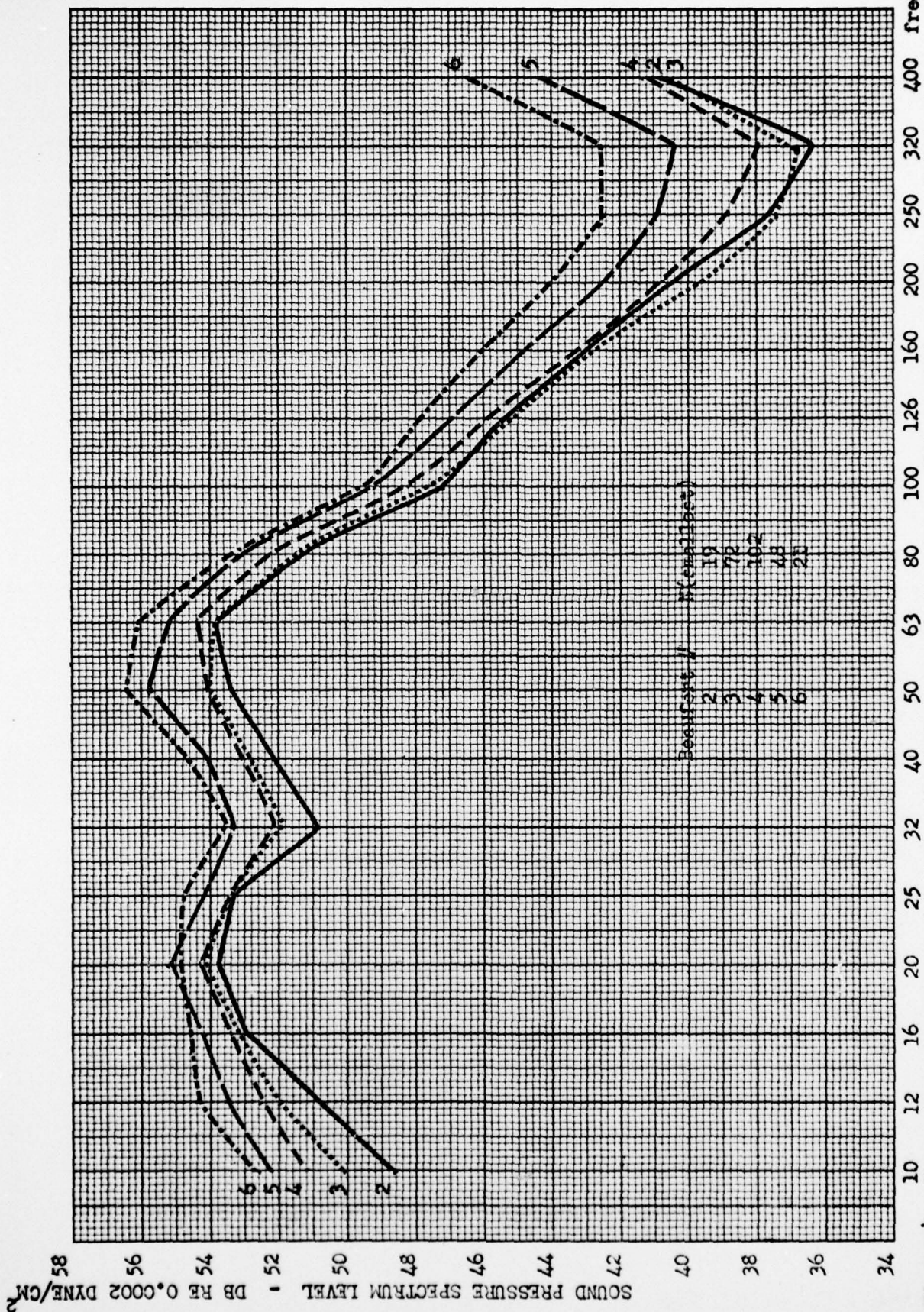


Figure 4. Mean of sound pressure level for the 3rd octave band centers. Data sorted according to Beaufort Numbers. Data for the hours 0000, 0600, 1200, 1800Z. For the area of wind averaged to a maximum radius of 200nm. Jan thru April 1963.

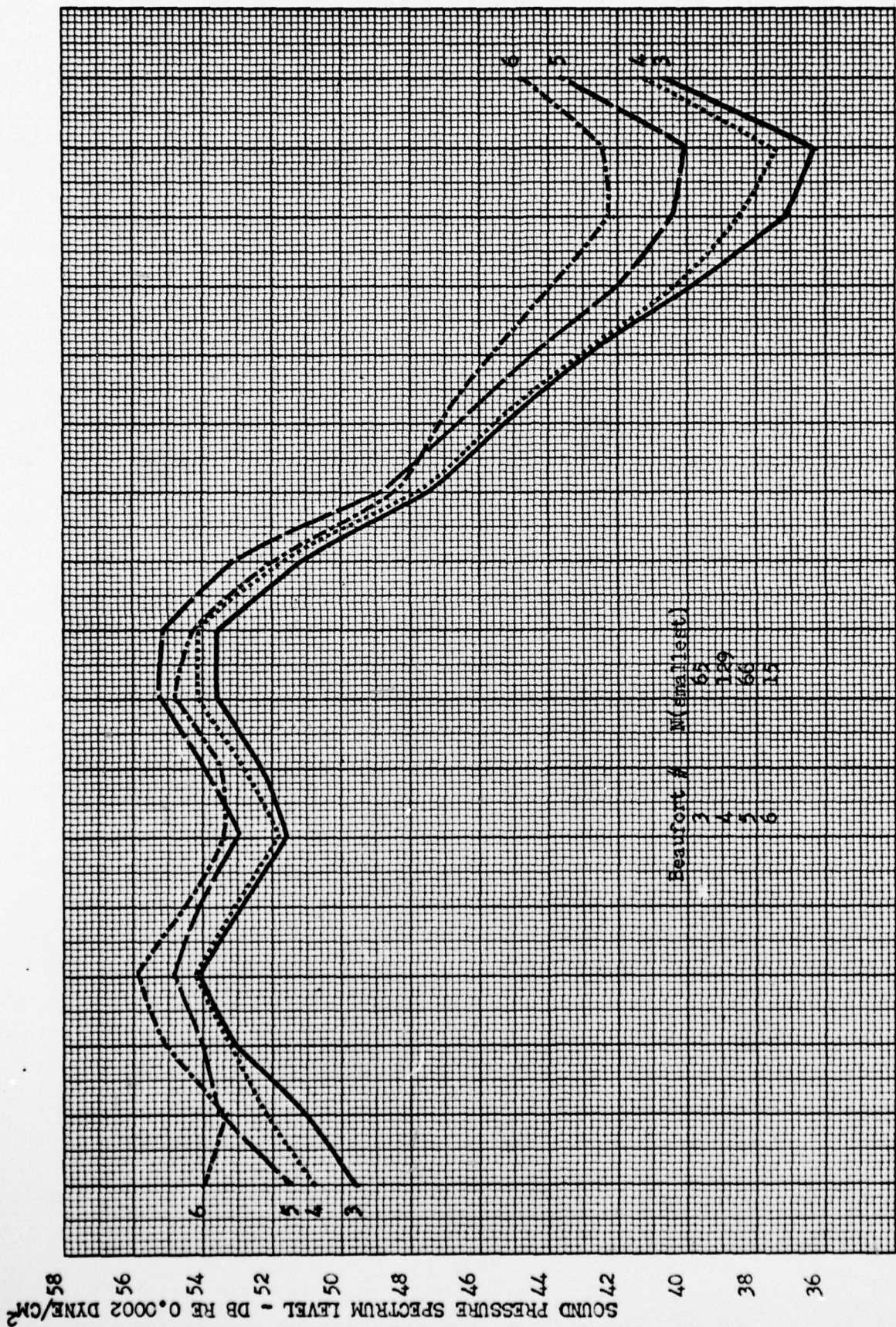


Figure 5. Mean of sound pressure level for the 3rd octave band centers. Data sorted according to Beaufort Numbers. Data for the hours 0000, 0600, 1200, 1800Z. For the sector of winds averaged to a maximum radius of 400nm. Jan thru April 1963.

SOUND PRESSURE SPECTRUM LEVEL, DB RE 0.0002 DYNE /CM²

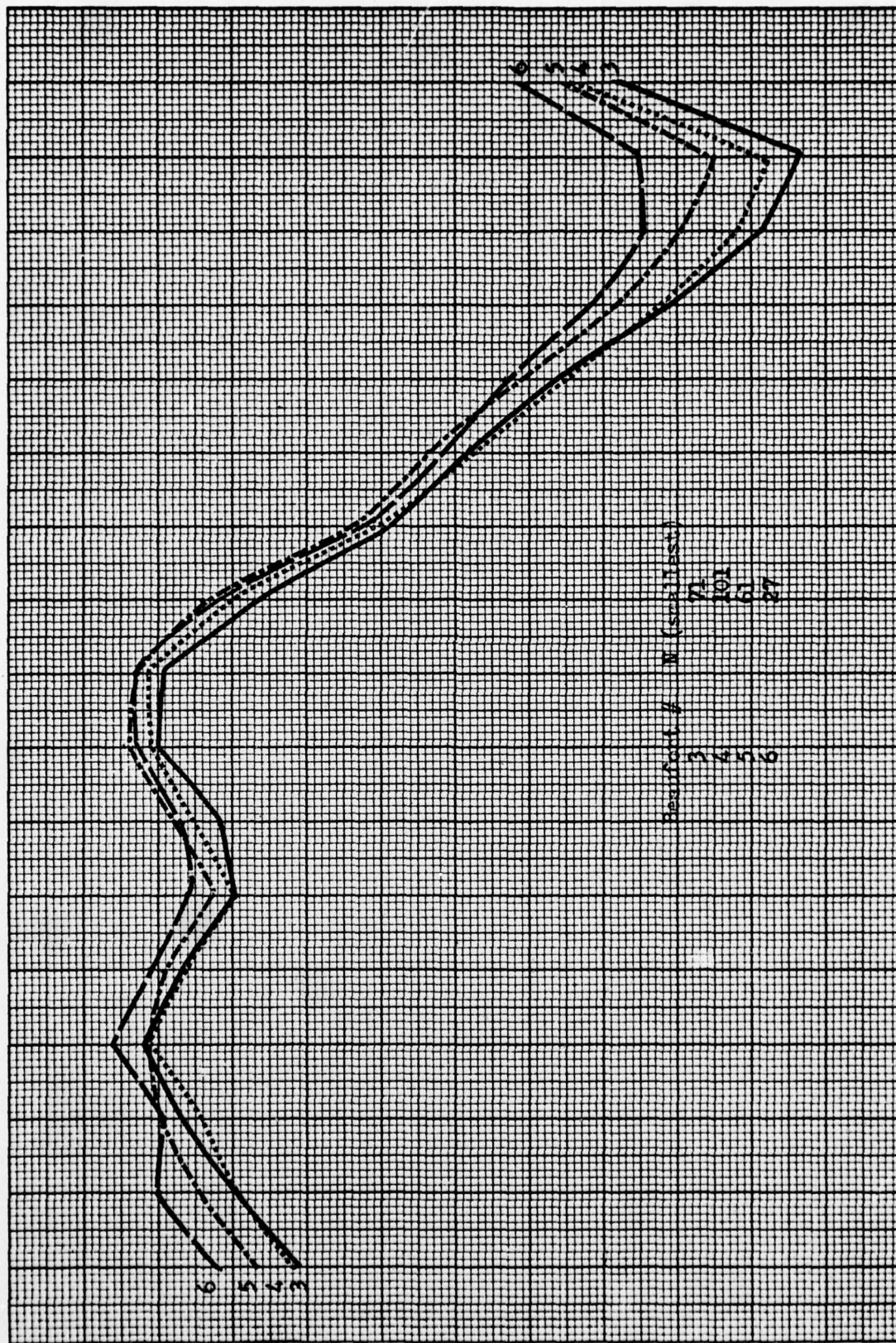


Figure 6. Mean of sound pressure level for 3rd octave band centers. Data sorted according to Beaufort Number. Data for the hours 0000, 0600, 1200, and 1800Z. For the shell of winds averaged to a maximum radius of 400nm from a minimum of 200nm. Jan thru April 1963.

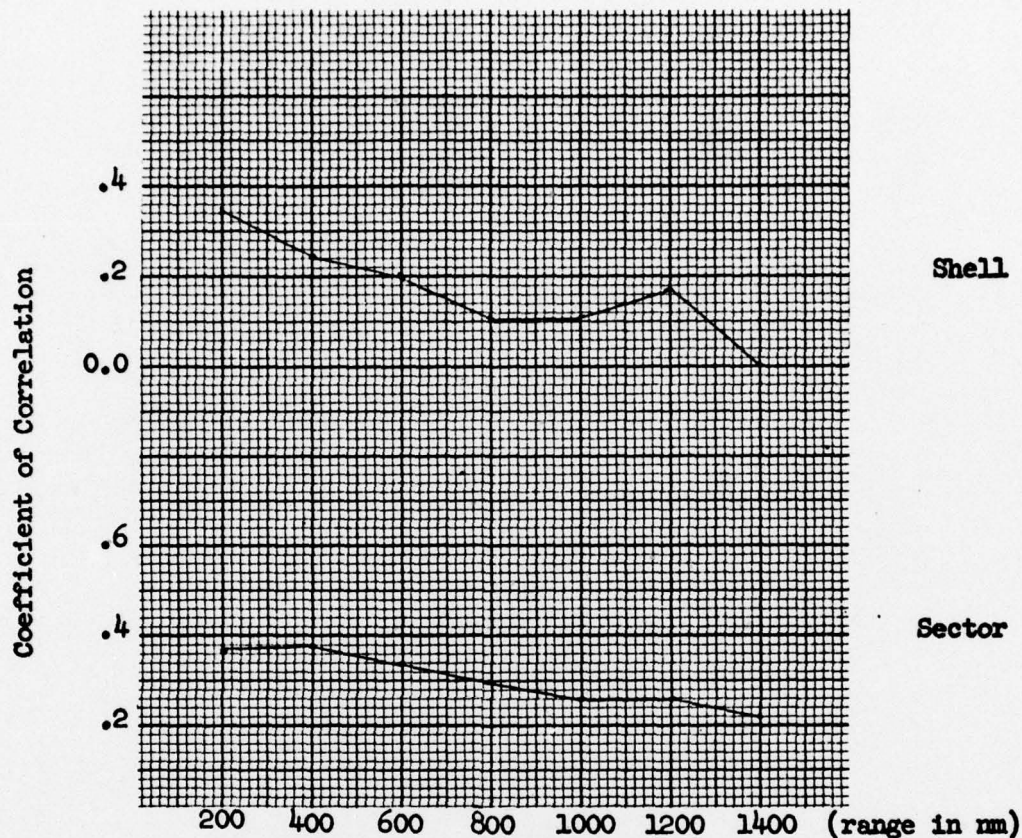


Figure 7. Coefficient of correlation between broad-band ambient noise and wind speed vs maximum range in each shell (top) and each sector (bottom).

Broad-band ambient noise (10 to 350Hz) dependence on near surface winds and their distance from the place of recording is indicated in the above figure. For the case of the sector analysis, dependence is shown for all ranges considered. The more rapid decrease in magnitude of the correlation coefficient for the shell analysis is also shown; here dependence is insignificant beyond a range of 800nm.